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Becoming Boundary Spanning Engineers: Research Methods and Preliminary Findings

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Abstract

A growing body of evidence suggests that practicing engineers are increasingly expected to act as *boundary spanners* who can participate in and manage diverse local and global teams, translate competing stakeholder demands into effective design solutions, and leverage expert knowledge from multiple fields and specialties. The larger project represented by this paper responds to this reality by proposing *boundary spanning* as a core *meta-attribute* for engineering students and early career professionals. This paper more specifically offers a detailed description of the study design for a major phase of this research project that involves conducting in-depth, semi-structured interviews about boundary spanning experiences with more than two dozen early career engineers in the manufacturing, construction, and electronics industries. To keep the scope of the present account more manageable, this paper provides a preliminary window onto our findings. We utilize a single case approach with a focus on three themes emerging from our analysis of two interviews with one research subject. Namely, we discuss transitions from school to internships to full-time job, the social aspects of engineering practice, and the emotional and psychological dimensions of professional work. One leading objective for this paper is to explore the utility of investigating the realities of engineering work through the lens of an overarching meta-attribute such as boundary spanning. We also propose that our findings provide valuable glimpses of engineering practice that might benefit students who are studying or considering studying engineering. This paper may additionally appeal to educators and researchers who are interested in qualitative methods and/or empirical studies of professional practice.

Introduction

A growing body of evidence suggests that practicing engineers are increasingly expected to act as *boundary spanners* who can connect teams in disparate geographic locations, translate diverse stakeholder needs into effective design solutions, and leverage expert knowledge from multiple disciplines. These next-generation professionals must be empathetic in the midst of competing perspectives, adept as both listeners and messengers, able to cultivate trust and mutual respect, and skillful at seamlessly integrating the social and technical aspects of their work. Such individuals are also ideally positioned to advance organizational and national competitiveness, address global grand challenges, and move into leadership roles. In summary, the success of current and future engineers depends on their ability to communicate, collaborate, and coordinate across many different kinds of boundaries.

The need for such capabilities – which we refer to using the umbrella term *boundary spanning* – can be traced back many decades, but has intensified in recent years due to globalization pressures, organizational restructuring, technological change, and other trends. As aptly framed by former NAE President William Wulf, "understanding other cultures, speaking other languages, and communicating with people from marketing and finance will be just as fundamental to the practice of engineering as physics and calculus".[1] Bordogna similarly asserts that "[d]emands are increasing for a holistic breed of engineers–graduates with the skill to work across intellectual,

social, and cultural boundaries",[2] while Duderstadt has advocated for "fluency across boundaries" and "integration of knowledge across an increasingly broad intellectual span" (p. 45).[3]

A growing body of scholarship adds further weight to such assertions. Studies by Lynn and Salzman, for instance, lead them to conclude that engineers urgently need "cross-boundary skills" to enable working "across disciplinary, organizational, cultural, and time/distance boundaries" (p. 82).[4] Research by Hanneman and Gardner has similarly identified boundary spanning skills and competencies as a key emerging requirement for college graduates, including engineers.[5,6] Demand for such capabilities also persists as professionals progress in their careers. In one study, 86% of more than 100 senior executives indicated that it is "extremely important" for them to work effectively across boundaries, yet only 7% believed they were "very effective" at doing so.[7]

The larger project represented by this paper responds to these challenges by proposing *boundary spanning* as a core *meta-attribute* for engineering graduates and early career professionals. This approach provides a robust framework for relating and uniting a host of complimentary technical and professional capabilities, including multiple ABET accreditation criteria. It also opens up new opportunities for innovations in instruction and assessment, while potentially offering a new lens for research on engineering practice. However, there remains a lack of understanding regarding what counts as boundary spanning in engineering work, including across industry sectors and career levels. Further, we know very little about how engineering students and early career engineers experience boundary spanning challenges, much less what instructional strategies best cultivate boundary spanning competence. These gaps are addressed through the project's three primary objectives, which are organized around a competency-based approach[8] to defining, developing, and assessing boundary spanning capabilities in engineering:

- Objective 1: Develop a typology of boundary spanning roles, activities, and competencies for multiple engineering fields.
- Objective 2: Design and evaluate an instructional framework to instill a *boundary spanning mindset* among engineering students and early career professionals.
- Objective 3: Create and pilot a situational judgment test (SJT) to assess key dimensions of boundary spanning competence in engineering practice.

The first phase of this project, as reported in other publications, involved identifying and analyzing more than 80 journal articles and book chapters on boundary spanning and related concepts using established procedures for a systematic literature review.[9] This process in turn informed development of an initial typology of boundary types, as well as a variety of boundary spanning roles, activities, and competencies that are potentially relevant to engineering practice.

This paper reports on the study design for a second major phase of this research project, which involves collecting data from more than two dozen early career engineers in the manufacturing, civil construction, and electronics industries. More specifically, we are first conducting semi-structured interviews with engineering students who have participated in internships and/or co-ops, as well as individuals in their first 1-2 years of full-time professional practice. Some subjects are also being interviewed twice to capture new experiences and changes in perspectives after switching job roles, or after graduating and starting their first full-time positions. Another group of subjects is being asked to respond to a series of guided reflection prompts during their

internship or co-op rotations, culminating with an exit interview. This work goes beyond investigating how early career engineers grapple with technical problems to more broadly study the nature of their encounters with boundary spanning situations and challenges, in part viewed through the boundary spanning typology and themes identified during the first project phase.

This paper offers additional details about the development and evolution of our ethnographic interviewing protocol, as well as our use of a primer document to help familiarize interviewees with boundary spanning and related concepts. We also report on our use of a critical incident approach to collect reflection data on boundary spanning from engineering students during their co-op or internship assignments. In terms of data analysis, we focus on our thematic analysis approach to coding the data. In addition to reporting select preliminary findings, we describe our plans for finishing this phase of the study, while also briefly reflecting on how our research might inform ongoing efforts to better align engineering teaching and assessment practices with the workplace realities faced by many of our graduates.

To keep the scope of this account more manageable, this paper reports on three specific themes that have emerged from our initial analysis of two interviews with a single research subject. As such, our account uses a single case approach, following in the footsteps of groundbreaking scholarship such as Foor et al.'s "ethnography of the particular" which recounts the lived experiences of one female, multi-minority student pursuing an engineering degree.[10] Our data analysis is ongoing, and in separate publications we will report results more specifically concerned with boundary spanning, including types of boundaries, boundary spanning roles and activities, and competency demands experienced by early career engineers. Our larger objective for this paper is to explore the utility of investigating the realities of engineering work through the lens of an overarching meta-attribute like boundary spanning. We also argue that our findings provide valuable glimpses of engineering practice that might benefit students who are studying or considering studying engineering. Further, we expect this paper will appeal to educators and researchers interested in qualitative methods and/or empirical studies of engineering practice.

Methods

Against the preceding backdrop and as part of a larger research project, the authors are investigating three main research questions during this phase of the study:

RQ1) What specific boundary spanning roles, activities, and competencies are most important and prevalent for early career engineers?
RQ2) How do early career engineers experience boundary spanning challenges?
RQ3) What learning experiences enhance the boundary spanning capabilities of early career engineers?

While our research questions and larger study design are specifically concerned with boundary spanning, the main phenomenon of interest is necessarily situated in the context of engineering practice. As a consequence, we realized during our data collection and analysis that our study might have the potential to more generally illuminate the lived realities of engineering work as experienced by engineering students and other early career professionals. This paper therefore

reports on a number of emergent themes, while other ongoing data collection and analysis efforts will be leveraged to more directly address the three research questions noted above.

Data Collection: Interview Methods

This research project started with three pilot interviews, two of which are the focus of this paper. These pilots initially supported development and refinement of our semi-structured interview protocol, which utilizes both critical incident[11] and ethnographic[12] approaches to data collection. The critical incident approach seeks to uncover specific situations or incidents of boundary spanning encountered by early career engineers. In order to uncover and probe these possibly challenging and emotional situations surrounding boundary spanning, the authors wanted to make sure to approach these conversations appropriately. Frank describes the ethnographic interview approach as one where building rapport is one of the key elements of the ethnographic interview (p. 19).[12] She also advises that the "interviewer must have no judgment: must not interrogate but, rather, ask respectful questions that demonstrate a willingness to see from the informant's perspective" (p. 23).[12] Other ethnographic approaches, such as field studies, have also shown considerable utility in making visible the realities of engineering work.[13] Our approach generally resonates with Stevens et al.'s claim that more ethnographic work is needed to understand engineering practice, including by looking beyond the "technical rationality that [Rosalind] Williams called the ideology of engineering" (p. 125).[13]

In order to take a field study perspective, an ethnographic semi-structured interview protocol was developed for this project, beginning with a grand tour question, i.e., "could you describe a typical work day?"[14] Starting with a question of this type allows the interviewee to respond broadly while helping to frame and guide the subsequent discussion, including by opening up opportunities for wide-ranging follow-up questions and probes. Our focus on boundary spanning in engineering practice allows us to explore engineering beyond technical work to a broader array of challenges and accomplishments, including those that are sociotechnical or even mainly non-technical in nature (e.g., situations that involve salient social, cultural, political, and other dimensions). Indeed, a growing body of scholarship argues persuasively that even highly technical engineering work often has deep and intrinsic social dimensions.[15]

Since our interviewees are likely not familiar with the concept of boundary spanning, the authors acted on a suggestion from colleagues to create a primer document to help sensitize subjects to the main phenomenon of interest. This primer was developed based on our growing knowledge of the extant literature, and is organized around four major sections.[9] To make the primer as usable and accessible as possible, we limited its length to just one page, and tried to avoid excessive use of jargon. The first part of the document, as shown in Figure 1, gives a broad definition of the term *boundary spanner*, followed by illustrations showing boundary spanners in three typical kinds of connecting or linking situations. These portrayals were informed by the results of our literature meta-analysis, namely in terms of seeing boundary spanners often framed as: 1) "linking pins" that connect people to other people and/or to the external environment,[16] and/or as 2) individuals who link otherwise disconnected individuals, i.e., they bridge "structural holes" in social networks.[17] The second part of the primer briefly describes three major kinds of boundary spanning activities (e.g., "Coordinating work tasks with others"), while the third section offers some types of boundaries that may be encountered by professionals (e.g., "Across disciplines,

professions, specialized areas of expertise, etc.”). A fourth and final section of the primer gives two brief vignettes as examples of typical boundary spanning situations encountered by early career engineers, one drawn from the literature and a second adapted from a pilot interview.

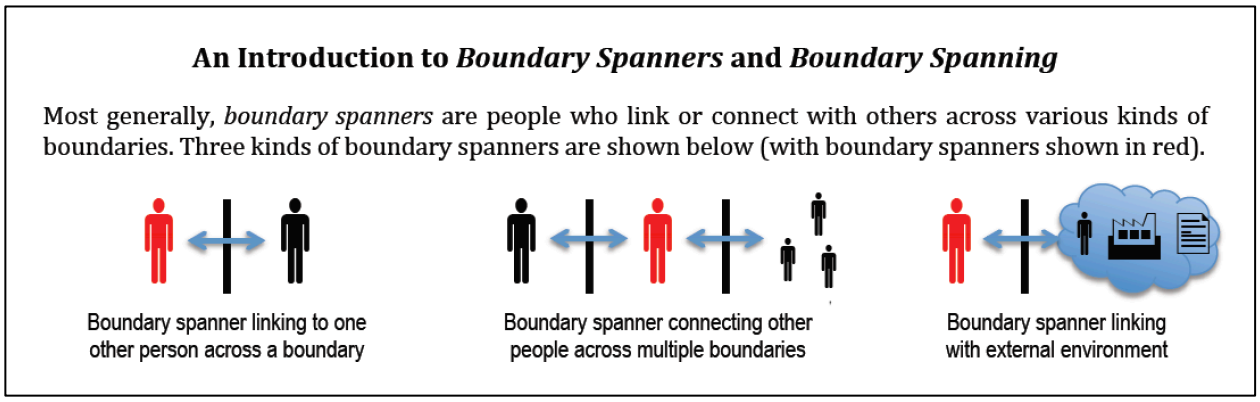

Figure 1. Header text and illustrations from boundary spanning primer document

In the current study, all interviewees are asked to review the primer document prior to their scheduled interview. For reference, a paper copy of the primer is also made available to subjects during all interviews. For the subject described in this paper, the interviewer provided him with a verbal overview of boundary spanning during the first interview, and then gave him a copy of the primer document to look over for the second interview. The primer was also shared with this interviewee so that he could review one of the vignettes that had been developed based on a boundary spanning work situation that he had shared during his first interview.

About the Subject: Andrew

The lead author conducted two interviews with a single subject, who we refer to in this paper using the pseudonym Andrew. At the time of the first interview, Andrew was an undergraduate engineering student in his final year of study in a Chemical Engineering degree program at a large Midwestern Research University. At the time of his first interview he had completed two separate internship experiences at two different companies in manufacturing or related work environments. A second follow-up interview took place two years into Andrew’s first full-time professional job. In both instances, the lead-author used the semi-structured ethnographic interview protocol described above. The interviews, each of approximately 60 minutes in length, serve as the data sources for this paper and were collected under Purdue IRB protocol number 1208012567.

Data Analysis

We used a hybrid deductive-inductive thematic analysis approach to analyze our interviews with Andrew.[18] Part of this process involved developing a codebook based on themes that emerged from a systematic literature review that is currently being prepared for publication in a separate journal paper, as noted above.[9] This codebook consists of four major categories: types of boundaries, boundary spanning definitions and roles, boundary spanning activities, and related competencies and attributes. Each category is comprised of more specific codes, and in some cases more specific subcategories. While detailed information about these categories and codes

is beyond the scope of this paper, we used this codebook as an initial guide our deductive thematic analysis. While looking for the codebook's themes, we were particularly attentive to let the data challenge and modify the codebook itself, including by allowing other themes to emerge from the data. The three authors applied this approach independently and met several times to discuss disagreement and to come to a final consensus on all coding decisions. During this process, we also paid particular attention to three emergent themes: school to internship to work transitions, the social dimensions of engineering professional practice, and emotional and psychological considerations. The remainder of the paper is focused on these emergent themes, while our findings more specifically focused on boundary spanning will be reported separately.

Findings

Our findings are organized in three main parts, each representing a theme or cluster of themes that emerged through our qualitative data analysis process. The first section is the broadest, focused on Andrew's learning as he transitions from school to internships to his first permanent job. The second section looks more closely at the nature of Andrew's work experiences, with an emphasis on the technical and social dimensions of professional practice and how these changed and developed during Andrew's work experiences. A third and final section turns to some emotional and psychological themes that surfaced through our analysis of the two interviews.

Game Changes: From school to internship to work

As noted above, our subject was interviewed during two periods when he was particularly well positioned to reflect and comment on key transitions in his educational and career trajectory. The first interview occurred as the subject was finishing coursework and approaching graduation. His resume at this point included summer internships at two different companies, and at the time of this first interview he had also recently accepted an offer for a permanent/full-time position in still a different company.

Early on in the first interview, the subject was asked about specific situations in either of his internship positions that proved surprisingly difficult, and/or involved unexpected resistance from others. Interestingly, the conversation quickly turned to a discussion about how his initial assumptions about the internship experience were very much inaccurate. As Andrew explained, "Because I am getting a university education for an industry job, I somewhat naively assume that the primary challenges that I encountered in the workplace would be academic in nature, or technical, right. That's not the case at all." As he then goes on to describe:

> The most difficult thing I did my entire first internship, the three months at [company name], in terms of actual technical work, was like a 30 second - oh, not 30 second - but it was like 30 minute, very short, design of a little Excel sheet to calculate heat recovered from a water stream using Q equals mcp delta t, which you learned like in high school. Like, its just literally multiplying numbers together, no integration, super simple, um, and yeah, that was the most serious thing I did. And I was astounded at the time, I was so surprised.

Later in the conversation, Andrew expands on the main challenges that he actually did face during his internships, characterizing them as "cultural." While we return to this theme below in

discussing the sociotechnical character of Andrew's work, here it is also worth touching on how he actually experienced the nature of his internships. Most generally, he reports that "in both positions I was essentially, like, my superior's lackey, really," and later goes on to explain: "You were just a lackey, you try not to get in the way, and yeah, and you're just trying to help."

Such statements strongly hint at both the short duration and lack of responsibility characteristic of many engineering internship positions. Reflecting on the first internship, he acknowledges:

> I spent a lot of time just sitting on my hands. Umm, 'cause I just, I would, I would go to my boss twice a day, hey, what you want me to do? Oh, I don't know man, umm, come back later today. Okay. Then I go sit in the bathroom stall for four or five minutes and play Tetris on my phone, like (Interviewer: [laughs]), no, no, I'm serious, like (Interviewer: I know), like, I, like I want to help so bad!

Nonetheless, there is evidence that Andrew learns to be more proactive in managing and even leveraging the considerable ambiguity of his internship roles. In fact, he describes how he gradually learned the importance of "staying earnest to yourself" and "trying to stay busy." He then talks about specific steps he took to seek out meaningful work in his second internship:

> I actually would go not just to my boss, but to like five other people that I had become friends with, right? Be like, hey, I got some free time, what are your projects, any way I can help? And more often than not I would get bites, you know. 'Cause if you just cast a net wide enough, you'll get something (Interviewer: Right.) And some of my biggest projects at [company name] came not from my direct supervisor, but from these other sort of independent sources that I sought out.

Andrew additionally notes that he always placed top priority on quickly completing work given to him by his primary supervisor, while also keeping his supervisor aware of his wider forays and side tasks. He goes on to note some observed benefits of this approach, particularly in terms of keeping busy, building and sustaining relationships across departments, developing a better understanding of the overall business, and improving his own visibility in the organization.

In an important sense, the preceding passages suggest that Andrew learns how to better play the "internship game" during his rotations through two different firms. Realizing the importance of staying busy and "being earnest", he develops new networking strategies to seek out projects and maximize potential benefits to both himself and the company during his short appointment. This situation likely stands in marked contrast to the kinds of situations Andrew often encountered in the academic environment, where he faced a fairly regimented workload that involved solving reasonably well-defined technical and other "academic" problems assigned by instructors.

Nonetheless, the second interview reveals yet another new stage of learning for Andrew, one where he is still coming to terms with playing the "career game." The second interview occurs nearly two years into his first full-time job, offering opportunities for reflection on both current and prior roles. When asked about his transition into full-time work, Andrew quickly noted that

the culture of the workplace was similar, but the temporal experience was completely different since "I'd only done them [the internships] for ten weeks." Expanding on this theme, he stated:

> I also think during my internships, don't tell my former employers, but I was able to get away with doing a lot less. I didn't really have any responsibility. Most of my day I spent, I would leave after seven or eight hours. I felt like I could get away with not necessarily doing very hard work or taking very challenging tasks because it wasn't expected of me, I was the intern.

Andrew then goes on to explain the reality of his current, full-time position, including some very intense periods of work involving long hours and working across multiple shifts to support new production equipment. Summarizing his experience in this new role, Andrew goes on to explain:

> Now, there's no escape. There's no ten weeks and you're done, you're there as long as you're going to be there. There's a mountain of work and eventually it's just expected of you. I feel like I really started to embrace the mentality of work really hard and try to get through it.

He goes on to describe how he frequently works ten-hour days to keep up with the workload. As this brief overview suggests, Andrew's transition into a permanent engineering role means a major increase in responsibility. As we discuss in more detail below, it also involves a notable increase in the amount of technical work he is doing, as well as intensified emotional and psychological challenges. Yet we also find that some of Andrew's largest challenges remain "social" or "cultural" in nature, again owing to his need to interface with diverse colleagues.

Sociotechnical Practice: Engineering work includes people in the equations

In experiencing a transition from engineering student to working professional, Andrew also became very aware of the socio-technical nature of his engineering job. In fact, he reports that most of his work was more social than technical, even during his time as an intern:

> Yeah, it's like a two-third, one-third split I think is a good way to approximate it. Two-thirds project, quasi-project management, doing non-technical tasks to accelerate your already existing project, or a project just starting, but with a pretty heavy hand of guidance from your boss, right? And the one third is technical work. Which isn't even really technical work all the time. I'm including stuff like revising AutoCAD drawings for the steam piping in the plant. Umm, other stuff like that.

Additionally, he explains that the technical work he was doing was quite trivial, while he was most challenged by the social and cultural nature of the task he was assigned:

> And I thought I'd be doing all sorts of intensive calculations, right? But the majority of challenges I encountered were cultural for sure.

During his internships, Andrew additionally became very sensitive to the different social groups existing in the company. For instance, when his boss assigned him to oversee the renovation of the company cafeteria, he noticed that there were two different groups he had to work with: the

contractors and human resources (HR). In that specific situation, he had to work as an intermediary between these groups to ensure that the project would proceed smoothly:

> It was really interesting because there were a couple of different groups, sort of tribes, responsible for portions of this. And they often had conflicting interests. Umm, one big group is the contractors who are actually doing it. And they just, like, [expletive] want to get done, right? They like, they just want to have their objectives clear, and finish installing everything, okay? Then there's like the HR people.

Moreover, he noticed that such patterns were not only salient in this one project, but also in the broader corporate environment in which he was situated. Andrew divided the people he worked with in three groups (business, technical, and operators), each with very distinct characteristics:

> There's three main groups in a manufacturing environment […]. The business team, right? And I include HR in that. Basically anyone with a non-technical background, but who is still focused on plant production or some other critical business role. […] Team number 2 is technical. Technical people. These include, umm, technicians who are actually happy with their jobs, okay? So the technical team isn't limited to just white collar, okay? You can have blue-collar people on the technical team, umm, that you can treat them the same as you would treat a white-collar engineer. And then the third teams is, maybe you will call them operators, that might be a misnomer, but its predominantly blue collar people who aren't as excited about their job, right? Don't want to take the time to share information because their excited about it, right? And are just trying to get through the day.

Looking at Andrew's behavior working with these different groups, it is evident that he had to learn how to strategically represent himself to diverse others. Indeed, he describes how he increasingly learned about "camouflaging who you were based on the company." He goes on to report that his ability to camouflage improved during his second internship as he became more adept at adapting his behavior and communication style based on the individuals and groups with whom he was interacting. He reports being meticulous in making sure that he was maintaining good relationships with everyone so that he could best accomplish the tasks he was assigned.

For instance, when interacting with business people he explains that it was very important to limit technical details and jargon because "if you go into technical details, they can see as an attempt to show that you're technically superior and they don't like that." With technical people, he reports that a key aspect was to get interested in and show excitement about their technical work, while his approach to working with operators was quite the opposite:

> …but the key is, you have to share their enthusiasm in problem solving, usually of a technical nature, okay? Umm, the operators, this is like, you have to seem the least enthusiastic.

As an intern, Andrew became acutely aware of these strategies. In fact, as he reflected on these same themes from the perspective of his work as a full-time engineer, he reframed the concept of camouflaging in terms of wearing different "masks" for the social contexts in which he worked:

> I think the mask you develop in a corporate environment is very divorced from the type of mask you have to develop on the factory floor, an industrial environment. The former is very professional, results-focused, calm, diligent. The latter is willing to laugh at unsavory jokes, willing to not necessarily report if someone's not wearing their gloves, right? Things like that.

While "camouflaging" or "masking" served as key examples of how the social and technical nature of Andrew's work often blended, he also shared accounts of several other sociotechnical roles and tasks he undertook. For instance, he explained that in his full-time position he had assumed the role of "intellectual gatekeeper," i.e., as someone who managed, coordinated, and suggested best practices rather than to more narrowly execute technical work tasks:

> You can almost think of my job and my boss's job as intellectual gatekeepers for the coating process on site. We set up procedures, we govern troubleshooting methodologies, we suggest best practices. Then it's up to the line teams to execute.

In Andrew's role as an engineer in a manufacturing setting, he spent much more of his time and effort working with people and thinking about how to successfully work with these people. This was again surprising to Andrew, as was also discussed regarding his expectations as an intern. Additionally, Andrew was not expecting so much of his effort to be focused on balancing the social, cultural, and technical components of his job, which in turn had psychological impacts.

Impact Force: The emotional and psychological dimensions of engineering work

As has been described in the preceding two sections, Andrew felt the need to strategically modify his behavior around certain people and groups, a trend that continued and intensified through his internships and into his first full-time position. As this section describes, Andrew was also surprised by the emotional impact of his work experiences. During his time as an intern, to begin, he struggled working in the midst of diverse stakeholders and needs, resulting in anger:

> And eventually I just got so pissed off. I was furious, I was so cranky, I hated coming to work.

Throughout his internship, Andrew started to more fully recognize the toll his job was taking on him. Indeed, at times he felt like his intellectual curiosity and motivation was suffering, and started to feel torn between the culture of academia and the realities of engineering professional practice. For example, as an intern, Andrew's excitement and enthusiasm was often squashed:

> And, umm, it's easy to get disheartened, it really is. Because you show up to work and you really, you know, you bring this attitude, like I want to make contributions, tell me what to do, like I'm willing to work. And it's, people are either too busy with their own [expletive], or, umm, they'll give you a little bit of

> an explanation, and you're like, oh, but, like, you just, 90% of the things you said are specific to this plant and I have no idea what you're talking about.

Similarly, another one of Andrew's experiences demonstrates his frustration as an intern, where he must again take into consideration the needs and desires of workers who typically have less formal education and are situated in lower-ranking positions on the factory floor:

> …but relative to all the GED [General Education Development] equivalent operators, who not only lacked the logical capacities that the university proves you have or instilled in you (Interviewer: Sure), right, but also have this huge chip on their shoulder about this, you know, [expletive] undergraduate coming in. He thinks he knows everything, right? So I'm just going to make his life difficult on purpose. And I encountered that a lot, a lot actually.

During his second interview, after working in his full-time engineering position for about two years, Andrew also reflected extensively on the emotional and psychological impact his work was having on him. Yet his comments suggest a significant shift in the nature of these impacts:

> I severely underestimated the psychological impact that doing this day in and day out forever has. I just couldn't hack it.

Andrew goes on to more specifically describe some experiences in his working environment, including how emotionally taxing it is for him to use the strategies necessary to be successful at his job in working with certain kinds of people. Andrew again discusses putting on a "mask" to build rapport with groups, but realizes how camouflaging may negatively impact his psyche:

> It's grating, because I feel as if I'm having to put on a mask and feign interests and pretend to have a certain level of cultural exposure and cultural tastes in order to be ... I don't really care about being accepted and being friends with them but it's that, if I'm not, I face a degree of hostility and I cannot effectively do my job. Does that make sense?

Another experience yielded a similar sense of frustration, in this case revealing marked tensions between his need to work effectively with diverse coworkers on the shop floor versus his wider range of professional and organizational commitments, including as related to safety concerns:

> There were a couple of times where honestly, someone was doing something against procedure and I brought it up and you would not believe the vitriol that I received. It made it unbearable to go to work. I was not able to function in my job. Not because I wasn't interested, but because I just got stonewalled on every front.

Pushing these ideas a little further, Andrew identifies still more situations he would much prefer to avoid. For example, when his coworkers are sexist and racist around Andrew he feels very discouraged, in part because of his ability to camouflage how he really feels in such situations:

> There's a lot of sexism. There's a lot of racism. There's a lot of almost subversive comments directed at the management and the daylight technical staff which they say around me, I guess, because I've done a pretty good job of putting on a mask

> and because I'm the junior guy. Maybe they're not just worried about it. It's depressing, man, it really is. Whenever they talk about a girl they always talk about how big her tits are, or, "I'd bang her", or, "She's really fat, gross." Those are the first comments.

Here again we find Andrew struggling to balance his own commitments, feelings, and interests with those of other people, many holding very different and even problematic views. This was also evident when Andrew's job required him to work late shifts, which led Andrew to realize that he did not want to give up on certain personal interests, including exercise:

> It's been terrible man. I've got to tell you, I have a lot of respect for people who do this. Not just in a manufacturing environment, but nurses, security guards, I can't live my life like this. It makes it, I've honestly found that it's really hard to have good quality of life outside of the office when you're living like that because I like to exercise a lot. I've really been passionate about weight lifting for the last two or three years, and it's really hard to pursue that outside of this. I have some activities that are a little more intellectual, and it's really hard to pursue any leisure activity that requires a significant amount of brain power because you're just drained the whole time.

Finally, Andrew explains that he is exploring the possibility of changing jobs, adding that "it's not necessarily driven by a negative experience at work, it's just that work has been really taxing." Andrew elaborates how his decision to change jobs relates to his frustration with perceived gaps between a more intellectual environment versus a manufacturing environment:

> That you have the best and the brightest, not trying to brag, you go to a top tier universities, you go through incredibly rigorous schooling at the hands of intellectual elites, academia elites, right? Then you end up in some back woods making [expletive] plastic. It's weird. I don't know. I'm excited to change jobs. I'm disillusioned. What are you going to do?

In addition to again pointing out a considerable gulf between the academic culture he had experienced and enjoyed at university as compared to his lived reality in manufacturing, he expands on this theme by commenting on still other dimensions of difference, including age:

> One of the technicians I work with, we started working together, he told me that he had underwear older than me. It's different. It's different. To be really frank, I've realized I don't necessarily enjoy being this entrenched in a manufacturing environment. I live a very cerebral life. I try to live a life of the mind. I like having casual conversations that are intellectually heavy. I like weaving philosophy and science in my everyday talks.

Andrew was very optimistic about his job; a hard-worker willing to make personal sacrifices to more effectively work with a diverse group of people. However, many of the behaviors that he perceived as necessary for success in this environment left him feeling emotionally spent – and perhaps even compromised. As a result, during the second interview he acknowledged that he was looking for another job that would be more intellectually and emotionally fulfilling.

Discussion

As the preceding findings suggest, the phenomena of boundary spanning may provide a unique and productive lens for investigating the lived realities of engineering work as experienced by early career engineers. While a comprehensive review of related literature is beyond the scope of this paper, here we tentatively discuss the extent to which the three aforementioned themes are visible in current scholarship. To begin, there seems to be a lack of in-depth research on the experiences of early career experiences and transitions among engineering students and professionals. For instance, the recent Cambridge Handbook of Engineering Education Research (CHEER) volume includes only two indexed references to the term "internships." [19] It appears that more attention has been paid to other kinds of career transitions, e.g., studies of engineers moving into management roles.[19] One notable exception can be found in Baytiyeh and Naja's study of the transition from college to employment among Lebanese engineers.[20] Still other studies have drawn attention to the disproportionate impact of internships on engineering students, including in terms of predicting increased retention in engineering degree programs, as a factor in career decision-making, and as a key mechanism for development of professional competence, to name a few salient themes.[21, 22, 23] Looking beyond the engineering education literature, one can also find engineers as subjects in broader studies of college-to-career transitions.[24]

Andrew's accounts of his educational and work experiences also open a small but insightful window into professional engineering work, confirming what scholars of professional practice have been suggesting for quite some time, namely "that the social and technical are almost inextricably tied up together"[13] (p. 120). In fact, Andrew's observation that "Two-thirds [is] project, quasi-project management, doing non-technical tasks" is surprisingly well-aligned with Travelyan and Tilli's finding that about 60 percent of engineering work is focused on interacting with other people.[25] Moreover, Andrew shared many examples of what Trevelyan calls "technical coordination", or "working with and influencing other people so they conscientiously perform some necessary work in accordance with a mutually agreed schedule" (p. 191).[26] Andrew's experience supervising the cafeteria renovation is a good example of the technical coordination work that many engineers frequently undertake. Thus, our findings provide further basis for critiquing dominant images of engineering work as being only or mainly technical rather than deeply and profoundly sociotechnical in nature.

The emotional and psychological dimension of engineering work, specifically in a manufacturing setting, was another surprise for Andrew. Emotion has begun to be considered more seriously in research in educational settings[27], but emotion specifically in the context of engineering professional experiences remains largely unexplored. A related consideration, empathy, has also surfaced as a topic of interest in studies of engineering education and practice.[28] However, the negative emotions and psychological challenges that Andrew encounters in each of his positions is somewhat distinct, calling for more consideration from an engineering practice point of view.

Conclusion

A stubborn lack of alignment between current workplace realities and the capabilities of graduates means that most early career engineers are simply not ready for boundary spanning work. As

Brunhaver et al. describe, many students leave school with "narrow views of professional practice" and employers find that most engineering graduates are "unprepared to practice."[29] These gaps are frequently reinforced by compartmentalized learning outcomes coupled with a segmented and crowded engineering curricula, in turn accentuating the boundaries between the technical and social/professional aspects of engineering practice rather than integrating them in a more holistic and authentic manner.[30,31] In addition to generating disillusioned students and employers, maintaining this status quo may erode the diversity, relevance, and influence of engineering degree programs and their graduates. Concerns have also been raised that such issues may be further exacerbated by ABET's recent proposal to streamline accreditation criteria for engineering degree programs.[32]

Our account of Andrew's experiences speak powerfully to these themes. At each stage of career transition, Andrew encountered a startling gap between his expectations and assumptions about professional work, on one hand, and his lived experience of that work, on the other. Fortunately, Andrew's personal characteristics (including personality, work ethic, attitude, etc.) likely gave him an advantage in these situations, allowing him to develop strategies to survive and even thrive when faced with ambiguous job roles, incalcitrant coworkers, and sharp increases in responsibility. Yet even the apparently resilient Andrew acknowledged the emotional and psychological toll of these challenges, to the point of exploring other employment opportunities and new career pathways.

As noted above, the remainder of our project will provide the evidence needed to identify and describe the full spectrum of boundary spanning challenges that are often encountered by early career engineers working in a number of industry sectors. This effort is ongoing, with 19 interviews conducted to date, and efforts initiated to collect guided reflection data from six engineering students as they progress through internship and co-op positions. We also anticipate that these data sources will shed further light on the major themes introduced in this paper, thereby responding to the limitation of a case study based on evidence drawn from a single subject's experience. In doing so, we hope to provide thick descriptions of professional practice that can inform efforts to bring the realities of engineering work into engineering courses and curricula, while also helping orient students to key challenges and issues they may face as they transition from school to work.

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